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Relating short-term measures to IMO's minimum 2050 emissions reduction target

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Introduction

In April 2018, the International Maritime Organization (IMO) agreed to its initial greenhouse gas (GHG) strategy during the 72nd session of its Marine Environment Protection Committee (MEPC 72). In addition to peaking emissions, reducing the carbon intensity of the global fleet, and achieving zero emissions as soon as possible this century, the strategy aims to reduce the international shipping sector's GHG emissions at least 50% below 2008 levels by 2050.[1] This begs the question: How does the sector achieve this target?

The strategy includes a list of short-, mid-, and long-term measures that could be used to reduce GHGs from the sector. Short term measures could be finalized and agreed by MEPC between 2018 and 2023, although the dates when these measures enter into force and begin reducing GHG emissions may fall outside this time frame. However, IMO plans to prioritize short-term measures that could reduce emissions before 2023.

The initial strategy lists many potential short-term measures, among them: improving existing energy efficiency frameworks; developing technical and operational efficiency measures for new and existing ships; and speed optimization and speed reduction. Mid-term measures could be finalized and agreed to between 2023 and 2030, with long term measures finalized beyond 2030. Mid- and long-term measures include developing an implementation program for alternative low- and zero-carbon fuels, operational energy efficiency measures for new and existing ships, and market-based measures. This analysis focuses on short-term measures, including how improving technical efficiency for new ships, slowing ships down, and introducing low-carbon fuels can increase the chances of achieving IMO's minimum 2050 emissions target.

Given that demand for shipping is projected to continue growing, achieving IMO's 2050 target will require dramatically reducing the amount of GHGs emitted per unit of transport work, e.g., per cargo tonne-nautical mile. This will require a major shift in ship operations, fuels, propulsions, and design. Before the end of this century, the entire international shipping sector aims to emit zero GHGs, which means that new fuels and technologies will be essential in decarbonizing the sector. Given the long lead time to bring innovative technologies to market, work on low-carbon fuels and technologies must begin now, even though the emission reduction benefits will be realized in the long term. In the short term, measures improving the ships' technical and operational efficiency are needed.

The IMO has promulgated mandatory energy efficiency regulations for international ships under the Energy Efficiency Design Index (EEDI). With some exceptions, the EEDI regulations mandate that new ships be increasingly less carbon-intensive than a baseline of similarly sized older ships according to the year in which new ships are built: 10% by 2015, 20% by 2020, and 30% by 2025. These regulations are subject to regular review. As such, they can be modified over time and new phases can be added.

The EEDI is the only legally-binding, mandatory energy efficiency regulation for international shipping. While the EEDI will result in only marginal emissions reductions in the short- and mid-term, mainly because of slow fleet turnover, the EEDI will have an increasingly large effect on efficiency and emissions in the long-term. Moreover, as new, more stringent EEDI standards are developed and implemented, the EEDI can drive innovation in the sector by promoting the use of innovative technologies (e.g.,

1 50% absolute emissions reduction from 2008 levels is the minimum goal and the "at least" qualifier could mean 100% emissions reduction in 2050.

wind-assist, hull air lubrication, etc.) and, eventually, promoting a shift to low emission and zero emission ships.

Whereas the EEDI applies only to new ships, meeting IMO's 2050 target will require improving the efficiency of the existing fleet as well. One way to improve operational efficiency is to slow down ships. In all but the most extreme cases, reducing speed reduces ship energy use and fuel consumption. Fleet-wide fuel consumption and emissions are also reduced even after accounting for the additional ships that are needed to maintain transport supply.[2] A speed reduction measure helps avoid rebound effects, or partial offsetting of expected emissions reductions due to unintended increases in energy use. Additionally, speed reduction may be easier to implement and enforce compared to an operational efficiency standard because speeds are observable through Automatic Identification System (AIS) data.

There are drawbacks to reducing ship speeds. First, slower ships mean more time and related expenses for each journey. Second, if a journey takes too long to complete, it can disrupt supply chains and spoil perishables, although some ships will probably be exempt from a speed reduction policy for practical, safety, technical, or economic reasons. Third, it can stymie innovation in energy efficiency retrofits for the existing fleet if a speed reduction measure is not tied directly to an operational efficiency target, particularly for ships that compete on time-of-delivery. However, ships subject to a speed reduction that do retrofit could outcompete their rivals by reducing fuel consumption, enabling them to increase profits or charge a lower freight rate.

This paper analyzes how improving the technical efficiency of newbuild ships and slowing ships down, along with the introduction of low-carbon fuels, could improve the probability of achieving IMO's minimum 2050 emissions reduction target. Significant volumes of low-carbon fuels will likely be needed to achieve IMO's 2050 goal as a long-term measure and, therefore, the results are particularly sensitive to the future availability of these fuels.[3] This analysis focuses on technical efficiency and speed reduction as short-term measures because there are clear near-term policy windows for strengthening the EEDI and for debating a speed reduction measure. MEPC 73, scheduled for October 2018, will consider whether to accelerate the implementation of EEDI phase 3 targets from 2025 to 2022. MEPC 74 in May 2019 likely will consider whether to develop new EEDI phase 4 targets. IMO delegates are now discussing how speed reduction might be used to reduce emissions, and these discussions are expected to continue over the next several meetings.

Methodology

ICCT researchers developed a model to predict future CO_2 emissions from the international shipping fleet, which we described in our April 2018 Policy Update on the IMO's initial GHG strategy.[4] In this analysis, we estimated the range of achievable 2050 international shipping CO_2 emissions as a function of business as usual (BAU) emissions, technical efficiency standards for newbuild ships, speed reduction, and availability of low-carbon fuels. Recognizing the uncertainties involved in predicting future outcomes, a Monte Carlo approach[5] was used to estimate international shipping CO_2 emissions in 2050 under various scenarios. The modeling inputs are presented in Table 1. A description of future work to refine our assumptions on low-carbon fuel supply, interactions between modeling inputs, and metrics for operational efficiency measures can be found in the appendix.

In this analysis, some modeling inputs are assigned values from a discrete set of possibilities. For example, we allow speed reductions to be 0%, 10%, 20%, or 30% from BAU speeds. For other variables, we assign values by choosing a mean value and a standard deviation and assume normal distribution; this results in a broader range of possibilities. For instance, we assigned a compound annual growth rate of 10% for the low-carbon fuel supply with a standard deviation of 5%, reflecting the large uncertainty of future low-carbon fuel supply for the international shipping sector. This implies an average supply of low-carbon fuels (sustainable biofuels, power to liquids, power to gas, etc.) of 3.7 exajoules per year (EJ/yr) in 2050.

2 Faber, J., Huigen, T., & Nelissen, D., "Regulating speed: a short-term measure to reduce maritime GHG emissions"(CE Delft, 2017), http://www.cleanshipping.org/download/Slow-steaming-CE-Delft-final.pdf.

3 Future supply of low-carbon fuels for transportation use is uncertain. It is not clear how much of the global supply of these fuels will be available for shipping, especially since cleaner, more expensive, alternative fuels would need to compete with relatively cheaper bunker fuel. More discussion on low-carbon fuel assumptions can be found in the appendix.

4 ICCT, *The International Maritime Organization's initial greenhouse gas strategy* (2018), https://www.theicct.org/sites/default/files/publications/IMO_GHG_StrategyFInalPolicyUpdate042318.pdf.

5 Monte Carlo approaches incorporate randomness into analyses to account for uncertainty in a given variable or variables. In this case, we ran the analysis 30,000 times while allowing the values of certain modeling inputs to vary randomly according to the rules set out in Table 1.

The Monte Carlo simulation was run 30,000 times based on the inputs in Table 1. Results were split into two different technical efficiency scenarios: (1) moderate technical efficiency improvement (13,340 iterations) and (2) accelerated technical efficiency improvement (13,229 iterations). The mean technical efficiency improvement and range under each scenario are presented in Table 2.

The moderate technical efficiency scenario is consistent with IMO's current schedule of technical efficiency improvements in the EEDI and assumes that new standards are developed in 2030, 2035, and 2040 which improve efficiency by 10% every five years. The accelerated technical efficiency scenario is the same, except that the standards are accelerated 5 years earlier, except for the 2022 case, which is 3 years earlier than the 2025 phase.

We also investigated the impact of speed reduction under each technical efficiency scenario. Thus, for our two technical efficiency scenarios, we compared 2050 international shipping emissions with 0% (baseline), 10%, 20%, or 30% speed reductions, giving a total of eight scenarios (moderate technical efficiency, 0% speed reduction; accelerated technical efficiency, 0% speed reduction, moderate technical efficiency, 10% speed reduction, etc.), each of which represented approximately 3,300 Monte Carlo iterations. For each of the eight scenarios, we calculated the proportion of results where 2050 emissions were at least 50% below 2008 levels (460 Mt or lower); this is the probability that the scenario results in achieving IMO's minimum 2050 emissions target.

Table 1: Modeling inputs

CO_2 emissions from international shipping	
2050	1,600 million tonnes
Newbuild technical efficiency improvement (g CO_2/dwt-nm) from EEDI baseline in the year indicated in the left column	
2022	20% or 30% (randomly chosen)
2025	2022 value +10%
2030	2025 value plus a randomly chosen value ranging from +0% to +20%, rounded to the nearest 5%
2035	2030 value plus a randomly chosen value ranging from +0% to +20%, rounded to the nearest 5%
2040	2035 value plus a randomly chosen value ranging from +0% to +20%, rounded to the nearest 5%
Low-carbon fuel introduction (exajoules, EJ)	
Date at which we begin modeling the introduction of low-carbon fuels	2030
Share of international shipping energy use supplied by low-carbon fuels in 2030	2.5% +/- 1% SD, normally distributed; values <0 are set to 0 Note: 2.5% of energy use in 2030 is ~0.3 EJ
Compound Annual Growth Rate (CAGR) of low-carbon fuel supply	10% +/- 5% SD, normally distributed; values <0 are set to 0
Result: Share of international shipping energy use supplied by low-carbon fuels in 2050	18% on average +/- 10% SD Note: 18% of energy use in 2050 is ~3.7 EJ
Speed reduction	
Speed reduction from BAU in 2050	0%, 10%, 20%, or 30% (randomly chosen)

Table 2. Moderate and accelerated technical efficiency scenario assumptions.

Scenario	Efficiency improvement by year: mean (range)				
	2022	**2025**	**2030**	**2035[a]**	**2040[a]**
Moderate	20%	30%	40% (+/- 10%)	50% (+/- 20%)	60% (+/- 30%)
Accelerated	30%	40%	50% (+/- 10%)	60% (+/- 20%)	70% (+/- 30%)

[a] Energy efficiency improvements in this year are at least as stringent as the previous period.

Results

Results of the Monte Carlo simulation are summarized in Figure 1. International shipping's 2050 CO_2 emissions are shown on the y-axis. Speed reduction increases as one moves from left to right along the x-axis. For each speed reduction scenario, we show how 2050 CO_2 emissions are affected by moderate technical efficiency (green) and accelerated technical efficiency (purple). Boxes represent the interquartile range; the thick black line within each box is the median value; the whiskers extend to the 2nd and 98th percentile. The probability (P) above each box plot represents the proportion of predicted 2050 CO_2 emissions (black dots) that fall at or below 460 Mt; in other words, P represents the probability that 2050 emissions are at least 50% below 2008 levels, the minimum goal for international ship emissions under IMO's initial GHG strategy.

There are many potential scenarios under which the international shipping sector achieves IMO's minimum 2050 emissions target. For example, assuming BAU growth in demand and emissions, the sector can achieve 440 Mt of CO_2 emissions, or 52% below 2008 levels, if all of the following conditions are met: (1) newbuild technical efficiency improves 30% from baseline in 2022 and 40% in 2025, increasing 10 percentage points every five years until 2040, where the efficiency improvement is 70%; (2) ships slow down 30% from BAU speeds, and (3) low-carbon fuels represent 2.5% of energy use in 2030, growing 10% per year, thus replacing 17% of energy demand and emissions in 2050. However, the technical efficiency stringencies, speed reduction requirements, and especially the availability of cost-competitive low-carbon marine fuels are all uncertain, leading us to consider a range of possible outcomes.

As Figure 1 indicates, accelerating the pace of newbuild technical efficiency and slowing ships down 20% or 30% results in 65% and 74% probabilities, respectively, of achieving IMO's minimum 2050 emissions target. Conversely, accelerating the pace of newbuild technical efficiency improvements without reducing speed generates a 44% chance of achieving the minimum 2050 target. Slowing ships down by 10%, 20%, and 30% without accelerating the pace of newbuild technical efficiency results in only 23%, 32%, and 42% probabilities of achieving the minimum 2050 target, respectively. These results ignore lifecycle emissions from low-carbon fuels. Had they been included, the probability of achieving the minimum 2050 target would be lower.

Under each speed reduction scenario, accelerating technical efficiency dramatically improves the probability of achieving the minimum 2050 target. For example, with 20% speed reduction and moderate technical efficiency, the probability is 32%; but with 20% speed reduction and accelerated technical efficiency, the probability doubles, improving to 65%. Similar results are observed for the other speed reduction scenarios.

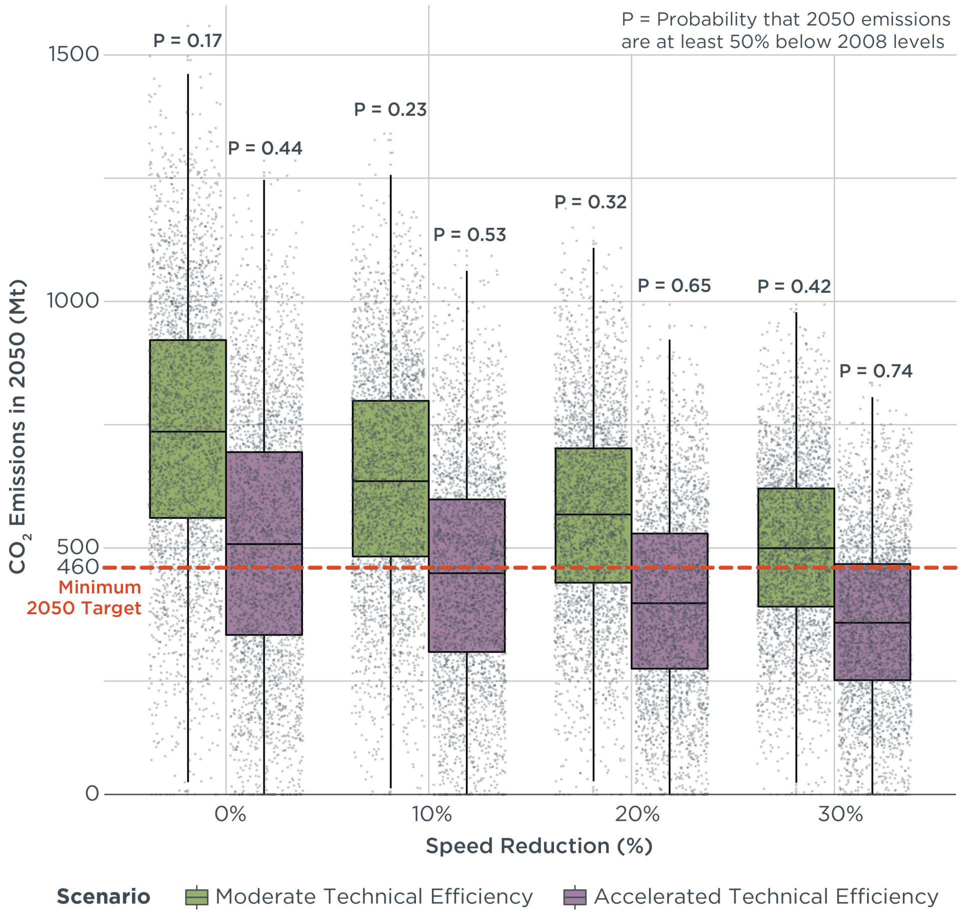

Figure 1. 2050 International shipping CO_2 emissions (million tonnes, Mt) and associated probability (P) of meeting IMO's minimum 2050 emissions target by improving technical efficiency and implementing speed reduction.

These results are sensitive to the assumed supply of low-carbon fuels in 2050. They are also sensitive to future BAU emissions projections, which we have set at 1,600 Mt in 2050. It is difficult to predict with certainty both of these future conditions as shipping demand has a major influence on BAU emissions projections. Global demand of low-carbon fuels, and the proportion of those fuels that will be available, feasible, safe, and economical for use in the international shipping sector, is highly uncertain. Therefore, the technical and operational efficiencies of the international fleet are easier to influence through policy than demand for shipping or supply of low-carbon fuels.

Conclusion

Accelerating newbuild technical efficiency standards by five years and reducing ship speeds improves the probability of achieving IMO's goal of reducing GHG emissions at least 50% below 2008 levels by 2050. There is a greater than 50% chance of achieving IMO's minimum 2050 emissions target if the following are implemented together: 2025

EEDI standards are implemented in 2022; new and increasingly stringent technical efficiency standards are implemented in 2025 and beyond; and ships slow down at least 10%. Accelerating technical efficiency standards without reducing speeds results in a less than 50% chance of achieving the minimum 2050 emissions target, as does slowing ships down without accelerating technical efficiency standards. Therefore, there is a clear benefit to implementing both measures together. Indeed, under each speed reduction scenario, accelerating technical efficiency standards approximately doubles the probability of achieving the minimum 2050 emissions target. The highest probability occurs when both the implementation schedule for newbuild technical efficiency standards is accelerated by five years and ship speeds are reduced by 30%.

These results are valid under the modeling assumptions described in the body of this paper. The future availability of low-carbon fuels for the international shipping sector and the future demand for shipping will also have an impact on BAU emissions in 2050. However, the finding that improving technical efficiency for new ships and slowing ships down can improve the probability of achieving IMO's minimum 2050 emissions target holds despite these uncertainties.

Other policy levers besides technical efficiency and speed reduction could achieve similar outcomes, including implementing an operational efficiency standard. Additional measures not modeled here could also improve the probability of going beyond the minimum 2050 emissions reduction target to help ensure international shipping emissions reductions are consistent with the Paris Agreement temperature goals. Careful consideration must be given to the design of efficiency measures to protect against undue market distortions, perverse incentives, rebound effects, and other unintended consequences. Stakeholder engagement and conscientious policy design can help alleviate some of these concerns while helping to achieve the initial strategy's emissions reduction goals, including phasing out GHG emissions from the sector a soon as possible this century.

Appendix: Future Work

In future work, we will focus on refining our assumptions on low-carbon fuel supply, interactions between modeling inputs, and metrics for operational efficiency measures.

LOW-CARBON FUELS

In our analysis, we assumed an average low-carbon fuel supply of 3.7 EJ/yr in 2050. Other researchers have used similar assumptions. For example, in an IMarEST[6] analysis on the cost of reducing GHGs in international shipping, they presumed 4 EJ of sustainable biofuel availability for the international shipping sector in 2050 as a central estimate, with a high of 11 EJ, excluding power-to-liquids and power-to-gas. However, some researchers are more optimistic about the maximum availability of these fuels, especially in the near-term. For example, the International Transport Forum (ITF)[7] found that deploying all known technologies could result in almost completely eliminating GHG emissions from the sector in 2035, mostly achieved through low-carbon fuels, including advanced biofuels, but also methanol, ammonia, hydrogen, wind, and batteries. Based on our analysis, this implies replacing approximately 14 EJ of energy with low-carbon fuels in 2035 and 20 EJ in 2050. For context, according to the International Energy Agency (IEA)[8] global transport biofuel production in 2016 was approximately 3.3 EJ for the entire transport sector. Nearly all of this supply is from conventional biofuels, such as ethanol, rather than advanced biofuels that offer greater lifecycle GHG emissions reductions and do not compete with food stocks. The IEA estimates that a maximum of 0.6 EJ of advanced biofuels could be available in 2020, but this would be split among the entire transport sector, of which international shipping represents approximately one-tenth of energy demand. Furthermore, adoption of low-carbon fuels could be hindered by their high cost, as most low-carbon fuels will be more expensive per tonne-nautical mile than bunker fuels.[9]

In our analysis, we ignored lifecycle emissions for both bunker fuels and low-carbon fuels. In the past, IMO has limited direct combustion emissions from the ships rather than lifecycle emissions, although the initial GHG strategy does list developing lifecycle GHG-intensity guidelines for alternative fuels as a short-term measure. All else equal, if lifecycle emissions from low-carbon fuels had been accounted for, it would decrease the probability of achieving the minimum 2050 target unless IMO augmented the 2008 emissions baseline by estimating lifecycle emissions for bunker fuels. Future work will seek to refine assumptions on the quantity, quality, and types of low-carbon fuels that could be available in the coming decades.

INTERACTIONS BETWEEN MODEL INPUTS

For the purposes of this exercise, we assumed that the effects of strengthening and accelerating technical efficiency standards, slowing ships down, and using low-carbon fuels were independent. However, there likely are interactions between the modeling inputs that our analysis does not explicitly account for. For instance, strengthening technical efficiency standards may result in slower ship design speeds, dampening the effects of a speed reduction measure for at least some newbuild ships. However, there is a distinction between design speed and the speed at which the ship actually operates; in the wake of the global financial crisis, some ships are operating well below their design speeds, although that may be changing.[10] Further, design speed is at least partly linked to installed power and some ships have minimum power requirements that could limit how slow they are designed to sail. If, however, technical efficiency standards do drive reductions in design speed, emissions would not decrease as much as we have estimated in the analysis. On the other hand, strengthening technical efficiency standards can drive demand for low-carbon fuels, which could increase the supply of those fuels for the sector and would serve to reduce emissions beyond what is estimated here. The net effect of these and other interactions will be investigated in future work.

METRICS FOR OPERATIONAL EFFICIENCY MEASURES

We investigated how speed reduction can improve operational efficiency, but other metrics besides operating speed could be used to improve the operational efficiency of the existing fleet. One approach would be a standard that reduces how much GHGs

6 IMarEST, "The costs of GHG reduction in international shipping," ISWG-GHG 3/3 (2018).

7 ITF, *Decarbonising maritime transport: Pathways to zero-carbon shipping by 2035*, https://www.itf-oecd.org/sites/default/files/docs/decarbonising-maritime-transport.pdf

8 IEA. *Tracking clean energy progress 2017*. (2017), https://www.iea.org/publications/freepublications/publication/TrackingCleanEnergyProgress2017.pdf

9 Hall, D., Pavlenko, N., and Lutsey, N. (ICCT: San Francisco 2018), *Beyond road vehicles: Survey of zero-emission technology options across the transport sector*. https://www.theicct.org/publications/zero-emission-beyond-road-vehicles

10 Olmer et al. *Greenhouse Gas Emissions from Global Shipping, 2013-2015*, (ICCT: Washington, DC 2017), https://www.theicct.org/publications/GHG-emissions-global-shipping-2013-2015. Olmer et al. found that operating speeds for the largest container ships and oil tankers had increased between 2013 and 2015.

are emitted when moving a given amount of cargo over a specific distance (CO_2e/t-nm). This would incentivize innovation in ships, especially those that compete on time-of-delivery because ships that are designed or retrofit to be more efficient will be able to sail faster than similarly sized ships that slow down to meet the standard. However, retrofits can require additional time in dry dock as well as upfront capital expenditures that ideally will be recuperated over time through fuel cost savings or higher freight rates; that assumes shippers are willing to pay a premium to transport goods on a more efficient ship. Lastly, such a standard avoids the rebound effect.[11]

While setting an operational efficiency target in terms of CO_2e/t-nm is the most straightforward way to ensure that GHG reductions per unit of transport work are realized, there are barriers to using this metric. First, most of IMO's focus has been on reducing CO_2 rather than CO_2e, which would account for other pollutants such as methane and black carbon. Second, many shipowners are hesitant to share information on actual cargo carried because they consider it confidential business information. Third, industry stakeholders have expressed significant concerns about how to baseline operational efficiency in a fair manner.[12] Therefore, alternative metrics have been proposed, including energy efficiency per service hour (EESH), individual ship performance indicator (ISPI), fuel oil reduction scheme (FORS), annual efficiency ratio (AER), and others. None of these alternatives directly account for emissions per unit of transport work. For example, in the AER metric, expressed as CO_2/dwt-nm, dwt-nm is a measure of transport supply rather than transport work. Using CO_2/dwt-nm as an operational efficiency metric is legitimate if a ship is fully loaded. However, a partially loaded ship would receive undue extra credit for improving efficiency because a lighter ship will burn less fuel and emit fewer emissions than a fully loaded ship. While there are economic incentives for ships to operate as close to fully loaded as possible, ships are not always filled to capacity.[13]

Future work will focus on ways to develop a fair operational efficiency metric that reduces emissions from the in-use fleet.

11 The rebound effect occurs when improving energy efficiency reduces operating costs and thus enables a ship to travel farther, speed up, or both while reducing or maintaining its overall fuel cost expenditures. If this occurs, the expected GHG emissions reductions from energy efficiency improvements are partly offset by increased fuel consumption. An operational efficiency standard reduces or prevents the rebound effect, whereas technical efficiency standards alone may not. However, the magnitude of the rebound effect associated with improving technical efficiency for ships is not, at the moment, well understood.

12 INTERTANKO, "Understanding CO_2 emissions and challenges in assessing the operational efficiency for ships", MEPC 72/7/1 and MEPC 72/INF.5, (2018).

13 See Appendix J of the detailed methodology for Olmer et al. *Greenhouse Gas Emissions from Global Shipping, 2013-2015*, (ICCT: Washington, DC 2017) that shows the ratio of average draught to design draught for ships. When a ship is fully loaded, it should be operating near its design draught. The detailed methodology is available at https://www.theicct.org/publications/GHG-emissions-global-shipping-2013-2015.